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Impact of subsidy reform on the kingdom of Saudi Arabia's economy and carbon emissions

Redouane Sarrakh *, Suresh Renukappa, Subashini Suresh, Sabah Mushatat

Faculty of Science and Engineering, University of Wolverhampton, England, United Kingdom

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ABSTRACT

Seeing the uprising economy and population of Saudi Arabia, some of its energy subsidies may be acceptable or even necessary to reach the country's social and economic objectives. Nevertheless, an over-subsidisation and poor implementation may lead these subsidies to deviate from their initial objectives or even contradict them. This paper uses the price-gap approach to estimate the size of energy subsidies in Saudi Arabia. The results indicate that the value of kingdom's energy subsidies amounts for $80 billion in 2012, representing 11% of the country's GDP. Oil products, gasoline and diesel, are the most subsidised followed by electricity and finally natural gas. The Input-output model was used to quantify the effect of a reform on the economy. The findings show that a total removal of energy subsidies with no social safety nets would affect negatively Saudi Arabia's economy and mostly the energy intensive industries, especially the quarrying and mining sector. However, a total removal of subsidies accompanied with a targeted cash transfer towards social and health sectors would affect positively the majority of the country's economy apart from sectors that relays heavily on energy consumption. The paper also proposes subsidies reform options, like implementing compensatory measures to cover the energy prices increase to protect the limited and low-income households, using and reinforcing the social safety networks to face any changes in energy prices.

1. Introduction

Saudi Arabia is one of the world's largest producers and exporters of oil and gas and its economy is mainly based on fossil fuels, the country is living a rapid economic and population growth since the eighties [1], this lead to a rapid acceleration in energy demand, which threatens the country's energy sustainability. The high demand and consumption pose a difficult question about the country's energy subsidies size, effectiveness and the efficient usage of its finite energy resources. Wu [2]; Cohen et al. [3] showed that the increase of energy prices might lead to an improvement in energy efficiency. Steinbuks and Neuhoff [4] indicated that in increase in energy prices resulted in smaller energy use within the manufacturing industry in 19 OECD countries, and Jamil and Ahmad [5] found that the electricity consumption could drop with the rise of its prices. Therefore, energy prices play an important part in setting energy demand, consumption and efficiency, and energy subsidies represent a crucial element for setting them up.

Saudi Arabia's oil and gas sector is by far the country's most important contributor in regard to the economy, as it accounts for 43% of the economy, 45% of the budget revenues and 55% of the country's global GDP [6]. The kingdom with 260.8 billion barrels of oil reserves [7], has the largest conventional oil reserves in the world. In terms of natural gas, although Saudi Arabia does not import nor export it, the kingdom holds the fifth largest natural gas reserves [8,9], as the gas is produced solely for internal consumption. In term of consumption, Saudi Arabia is the largest consumer of petroleum products in the Middle East, with more than 3 million barrels per day, doubling its consumption since 2000 [10], putting the country's consumption amongst the highest in the world (13th), ahead of countries with larger populations and economies, such as Germany and Canada, with the German population about three times the population of KSA with an economy nearly six times that of KSA. In term of CO_2 emissions, the kingdom's emissions has increased sharply since the late 1990s, as the CO_2 intensity is risen yearly by 2% since 2000 [86], about 291 thousand kiloton from liquid fuel consumption and 102.2 million metric tonnes from diesel and gasoline consumption in 2011 [11].

Seeing Saudi Arabia's endowment in oil resources, the Saudi citizens believe that they are entitled to low energy prices as a way of benefiting

* Corresponding author.
E-mail addresses: R.Sarrakh@wlv.ac.uk (R. Sarrakh), suresh.renukappa@wlv.ac.uk (S. Renukappa), S.Subashini@wlv.ac.uk (S. Suresh), s.mushatat@wlv.ac.uk (S. Mushatat).

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from the state's fossil fuel wealth [12]. In addition to that, cheap energy prices for essential commodities like electricity, gasoline and diesel give the poor and limited income households the opportunity to meet their necessary needs in terms of energy. The subsidies also contribute at controlling the prices of energy, especially with the high volatility of the international fuel prices, thus controlling the country's inflation rate [13–15]. That is why governments, precisely in developing countries, prioritize energy subsidies over other mitigation measures that would benefit either socially or economically the poor class of the country [16]. Furthermore, governmental officials consider energy subsidies as an integral part of the macroeconomic policy, as they set the country's targets in terms of society, economy and environment [17].

Because of high energy consumption, Saudi Arabia is facing some severe energy related challenges, from consumption unsustainability to high Carbon Dioxide emissions, making energy subsidies a serious matter that has to be dealt with in the nearest future, as they encourage reckless usage of energy amongst end user consumers and producers, which will affect the country's energy efficiency. The reform of energy prices is one of the solutions that the government could adopt, for sure, it will affect the social, economic and environmental sectors of the country, depending on the type and option chosen for the subsidy reform, and it will affect the various society groups differently depending on income and consumption habits. In fact, the government of Saudi Arabia took some actions relating to energy subsidies reform, and the sharp decrease of oil prices represented the best opportunity for that [18]. Al-Naimi, Saudi Arabia's Minister of Petroleum and Mineral Resources along with the world's leaders met at COP21 talk in Paris, and the Lima Accord to discuss and negotiate a possibility of eliminating the fossil fuel subsidies and implementing measures such as the carbon tax on most of the counties for environmental, social and economic reasons [19]. Besides the promise of energy prices reform, Saudi Arabia is also planning to invest in nuclear energy and implement carbon capture and storage technologies within some of its oil wells to reduce Carbon dioxide emissions [88]. Furthermore, with the kingdom's economic future orientation of moving away from oil, a subsidy reform should be an imperative step towards that [20].

The purpose of this paper is to assess the magnitude of energy subsidies and their effects on Saudi Arabia economy during 2012, but unlike the previous studies that had only quantified Saudi Arabia's energy subsidies, this study adds by evaluating not only the environmental effects of a subsidy policy reform on the kingdom, but its effects on the economy using the input-output model. The economic impacts of this policy change are analysed through two separate scenarios: A subsidy removal with and without a redistribution of savings. The study is composed of five sections. Section 2 would review the available literature regarding energy subsidies. Section 3 will give an introduction of the method used to estimate the country's energy subsidies and estimate its scale for the year 2012. Section 4 presents the findings, evaluate the impact of the energy subsidies on the economy's different sectors and a proposition of price reforming possibilities that could be adapted by the government. Section 5 will include the conclusion.

2. Literature review

The 2010 G-20 Summit in Toronto proved the differences in the International organisations' definition and estimation of energy subsidies, and the great differences in their amount is a solid proof of that [21]. Seeing the disagreements regarding the definition of subsidies, the Agreement on Subsidies and Countervailing Measures [22] sets up conditions that must be met to consider any form of assistance as a subsidy. First, the assistance had to be in the form of a financial contribution from either the government or a public entity located within the country of domain. Second, these contributions need to benefit whomever they were given to. This agrees with the U.S Congress Joint Economic Committee (1972) (in Clement et al. [23] definition, as they define subsidies as any form of governmental assistance to either private producers by increasing their return or end-user consumers by getting goods or services under their economic costs. These subsidies could be in the form of cash, credit, taxes or procurements [17].

Improving the social welfare of the country, strengthening the economic development and winning the citizens support for political considerations are amongst the many reasons governments implement energy subsidies [24,25]; [87]). However; they also induce inefficient use of energy and encourage waste, they might as well push heavy industries to a high use of oil and gas resources [26], moreover analysts argue that the untargeted subsidies could be socially regressive and pervasive [27,28], seeing that the high-income households would benefit more from these subsidies. Barnett [29] believes that fossil fuel subsidies are harmful to both, the economy and environment, but the only reason for their existence is a political one, that is why it is very complicated to remove them.

Most of the available literature regarding energy subsidies, only concentrates on the size of subsidies and not their effectiveness [26]. Larsen and Shah [30] research is one of the most famous studies regarding energy subsidies, their definition, method of estimation has been the base for International Energy Agency (IEA) and several other studies. By 1992 the world's fossil fuel subsidies amounted for $230 billion, back then the former Soviet Union's subsidies represented up to two thirds of the world's, followed by China, while Saudi Arabia subsidies size was $2.2 billion. Burniaux et al. [31] estimations using the Green model fell in line with Larsen and Shah findings as they estimated the world's energy subsidies as $235 billion for 1992 in 1985 prices and exchange rate. The dissolution of the Soviet Union back in 1991 caused the worldwide fossil fuel expenditure to fall from $330 to $230 billion between 1985 and 1992 [89]. The fossil fuel subsidies amounted to $10 billion in the OECD countries and up to $48 billion in twenty of the non-OECD countries between 1995 and 1996 [89]. The Greenpeace International [32] and Rajkumar [33] showed that up to 90% of European subsidies are provided to energy or energy related industries between the years 1990 and 1995, and only 9% of the total subsidies went to renewable energy.

Meyers and Kent [34] estimated the world subsidies to be $1.11 trillion with $145 billion dedicated to energy, a $110 billion of it is in the form of negative subsidies, meaning that they are harmful to both the economy and environment in the long run, and most of it happened within the non-OECD countries [35]. De Moor [36] found out that subsidies relating to energy sectors represent the highest amongst other sectors, with a value of $240 billion worldwide, the author also showed the detrimental effects of fossil fuel subsidies and urged governments to remove them. The European Environment Agency [84] estimated energy subsidies to amount for $29 billion, not counting external costs, but the interesting thing is that European countries spent $7.5 billion on non-oil energy, $2.2 billion for nuclear power and $5.3 billion for renewable energy. Based on the IEA [37]; government of the biggest non-OECD countries provided $220 billion on energy subsidies, where $170 billion went to fossil fuel, and by 2007, the size of subsidies in the same twenty countries increased to reach $310 billion (IEA, 2008). The global amount for subsidies had been increasing until mid-2014, where the gap between the international and end-user prices started to become closer due to the decrease of oil prices. The fossil fuel subsidies for 2015 were estimated to be around $320 billion, about $180 billion less than 2014, which was close to $500 billion (IEA, 2015).

There is not a lot of literature covering Saudi Arabia's energy subsidies, their exact size or effectiveness. The kingdom subsidises its fossil fuel resources (oil and gas) and electricity by adopting several measures that enables these products to reach consumers at prices lower than the global market. The Saudi government deals with the payment of the price differences to preserve a standard consumer price or undercut their costs. For instance, Saudi Arabia sells 1 L of diesel at US $0.12, while it is sold at US $0.4 in the international market. Therefore, the Saudi government pays about 70% of the bill of diesel consumed locally, as it sees subsidies as an easy approach to distribute the country's financial benefits amongst its citizens without going into complex administrative processes [38]. However; Parajuli et al. [39] argued that these subsidies are amongst the challenges facing the country to implement more environmentally friendly solutions, such as renewable energy technologies, within its energy mix.

The financing of energy subsidies differs from one country to another, as it depends on several factors, such as whether the country is an exporter or importer of specific fossil fuel product, the ownership structure of the energy sector and the financial condition of the government [38]. For Saudi Arabia, being a net exporter with high income, the decision makers rationalise the low energy prices to the country's endowment in oil resources and low cost of domestic production. The low-end energy prices sold to Saudi citizens are not considered as an explicit subsidised fossil fuel, since the government is not explicitly making any financial contribution. In other words, the national oil company (Saudi Aramco) is selling its products at a price lower than the international market while ensuring they are higher than the production costs. So, the company is not incurring any financial losses and therefore the government is not paying them to compensate for any financial losses. However, it should be noted that these low energy prices could be considered as an implicit type of subsidies, since they represent a wasted possible economic revenue when selling fossil fuel products at a lower price than the international market.

Larsen and Shah [30] estimated the value of Saudi Arabia's energy subsidies to be $2.2 billion, amongst the world's highest subsidies providers at that period, the country subsidised mainly heavy fuels and other oil products, while the light fuels' prices were close to international prices. Fuel prices in Saudi Arabia are among the lowest in the whole world, gasoline for instance costs only 20 cents, which represents about 30% of the international price [40,41]. Based on IEA data, the Saudi government payed $32.5 billion on energy subsidies in 2009, the amount increased in 2010 to reach $46.6 billion and $60.9 billion in 2011, most of it on oil [42,43], it was ranked second in the world behind Iran who spent $82.2 billion in the same year. However, Alyousef and Stevens [44] criticise the method used by the IEA to estimate Saudi Arabia's energy subsidies, they argued that the kingdom's important position in the oil world and its ability to set the market prices makes the method used by the IEA flawed; they estimated the value of Saudi's energy to a value of $5.02 and $5.95 billion between 2002 and 2009. Both the IEA and Alyousef and Stevens used the price-gap approach method, the difference was in setting the reference price when calculating oil subsidies, IEA used the international prices as a reference price, while Alyousef and Stevens used the cost of production.

3. Methodology

The first step of the methodology is to quantify the amount of the Saudi energy subsidies using the price-gap approach covering oil products (Diesel, Gasoline, Fuel Oil and Kerosene), natural gas and electricity. Then this is followed by evaluating the effects of an energy subsidy reform policy on Saudi Arabia's energy consumption, using the constant elasticity inverse demand function, carbon dioxide emission and the kingdom's economy using the input-output model (see Fig. 1).

3.1. Price-gap approach

Several approaches are applied to estimate energy subsidies all over the world. But the amount of subsidies spent differs greatly based on the method used for the estimation [45]. The Effective Rate of Assistance (ERA) is one of the used approaches; it measures the net incentive on activities that produce tradeable goods. These incentives are in the form of border tariffs, taxes and non-border interventions, basically any form of assistance from the government to an industry that influence the return to value of a certain product. The Producer Support Estimate (PSE) (formally known as The Producer Subsidy Equivalent) is the required financial compensation that is given to a producer for an income loss because of a removal of a policy measure. The Inventory Approach could be considered as a unified framework, since it is derived from the

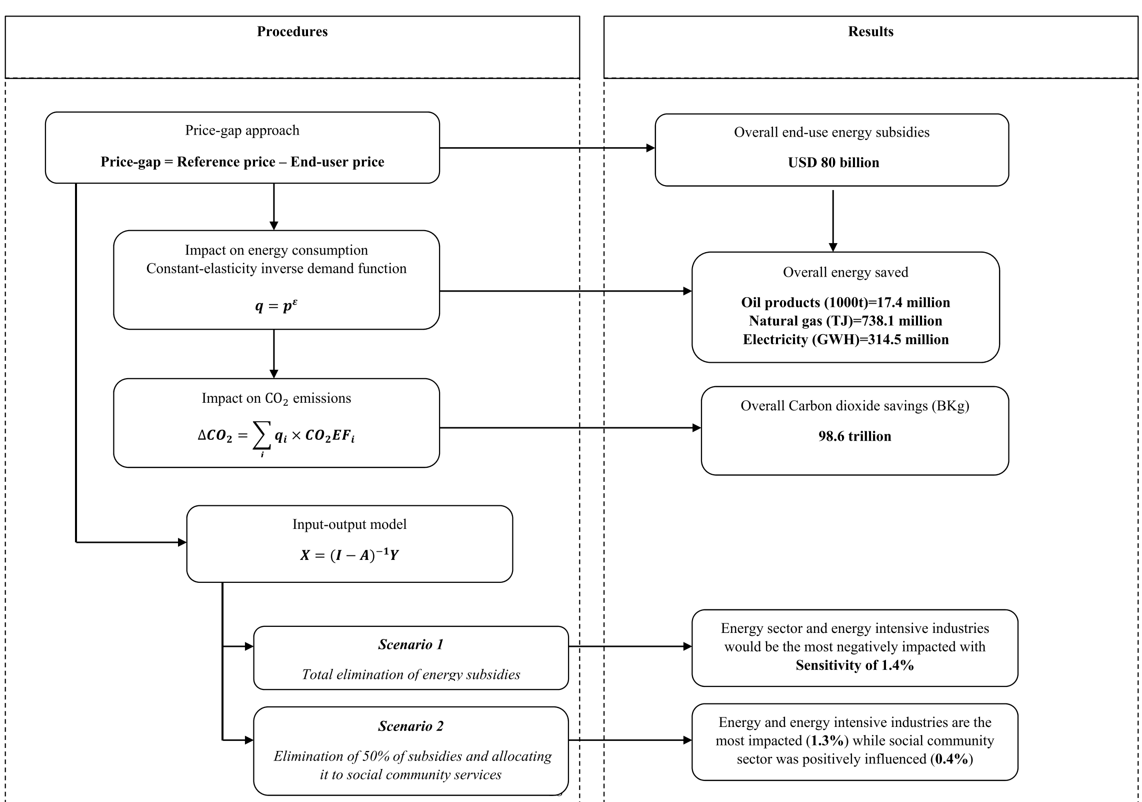

Fig. 1. Overview of methodology used.

Producer Support Estimate, Consumer Support Estimate and the General Service Support Estimate frameworks, making it covers all measures of subsidies [45]. Unlike other subsidy measurement methods, the Price-gap approach is utilized to quantify only consumer subsidies. The approach is established on the difference between the reference prices and the retail prices (consumer price), which means comparing the local market and the international market price of a tradeable good [46].

Theoretically, the ERA framework captures the full meaning of subsidy measurement; nevertheless, it is quite difficult to be applied in practice since it requires a great load of solid and reliable information and data, which can be hard to obtain sometimes. Regarding the PSE, the framework has been developed to be applied in the agricultural sector, so it still needs work to measure properly the fossil fuel subsidies. The inventory approach hand could be considered as a complete framework, because it unifies several measure estimations, it has also the capacity of quantifying the magnitude of impacts overtime. However, obtaining information and data regarding the supply subsidies is difficult. Therefore, this paper will apply the price-gap approach method, described by IEA [35].

Choosing the price-gap approach as the framework for this paper was based on several reasons. Firstly, the framework is the most used when it comes to estimating fossil fuel subsidies, in addition to the IEA, Kosmo [47]; Larsen and Shah [30]; Morgan [48] and Coady et al. [49] applied it in their research. Secondly, most of KSA's energy subsidies are in the form of customers' subsidies since the country is the second largest provider of energy subsidies based on the IEA [77] World energy outlook. Finally, the framework has the advantage of being relatively simple compared to the other methods.

The price-gap approach might be considered conceptually and analytically simple and widely applied, however; it also has limitations. First, the framework only captures end-users subsidies and does not include subsides for research, development and production, which could cause an underestimation, mainly in developed countries, creating thus a subsidy "blind spot" [40], especially since governmental energy organisations are amongst the largest beneficiaries of governments' subsidies [50]. Second, accurate data is needed, regarding the reference prices, retail prices, internal taxes and costs of transports and finding such data can be difficult [46].

The research will compare the situations of with and without subsidies in KSA, with everything else equal, regarding energy consumption and carbon dioxide emissions. The removal of energy subsidies will surely have dynamic effects rather than static ones, making the obtained results an underestimation of the actual situation.

3.1.1. Steps of quantitative analysis

The first step is determining the end user prices and the reference prices for fossil fuel, then computing the price-gap and subsidies for each form of energy [35].

$$Price\ gap = reference\ price - end\ user\ price \tag{1}$$

$$Subsidies = Price\ gap \times Units\ consumed \tag{2}$$

The end-user price is the existing retail price available to energy consumers, all costs are included (taxes, levies, fees …). The reference price can be more complex to determine, it can be either the price of the tradeable good in a competitive market (depending if the country is a net importer or exporter) or the long run marginal cost of production costs (LRMCP) [26]. For products that are traded internationally, such as diesel and gasoline, the reference price is the international market price, this choice is not without flaws, as energy products' international market prices do not usually conform to the theoretical definition of a competitive prices since the oil and gas market itself do not follow the behaviour or conventional competitive markets [51]. While for non-tradable products, such as electricity, the reference price is determined using the LRMCP.

The second step of the analysis is quantifying the impact of the subsidies, which is seeing the impact of removing the subsidies on energy consumption and carbon dioxide emissions. The method used in this research to quantify the effect of energy consumption is the same one described in the IEA [35]; it is based on the constant-elasticity inverse demand function. The method combines the changes in goods' prices (the price gap) with the elasticity of demand, yielding the potential change in consumption that is caused by the elimination of subsidies. This approach represents a suitable foundation for the estimation of subsidies influence of energy consumption, and therefore the country's energy security and the decrease of GHG emission caused by subsidies removal. The formula for it is as follows:

$$q = p^{\varepsilon} \tag{3}$$

By introducing dln: $$lnQ_1 = \varepsilon \times (lnP_1 - lnP_0) + lnQ_0 \tag{4}$$

Then, it will be possible to calculate the impact on consumption in the case of the removal of subsidies using: $$\Delta q = Q_0 - Q_1 \tag{5}$$

q & p: Energy price and consumption respectively.

Δq: The difference of energy consumption when subsidies are removed.

Ɛ: The long run price elasticity of energy demand.

P_0 & Q_0: Original energy price & consumption respectively.

P_1 & Q_1: Energy price & consumption after the removal of energy subsidies.

To estimate the new carbon dioxide emissions due to energy subsidies removal, the following equation should be computed:

$$\Delta CO_2 = \sum_i \Delta q_i \times CO_2EF_i \tag{6}$$

ΔCO_2: The reduction of carbon dioxide emissions.

i: The ith form of fuel.

CO_2EF_i: The carbon dioxide emission coefficient.

Seeing that Saudi Arabia is a net exporter of oil products, the reference prices are based on the export parity price: the price of the product at the nearest international hub [42,43], the price is adapted to quality differences minus any port costs, plus the cost of transport, marketing and VAT. Regarding electricity, since KSA does not trade it on an international level, the reference price is based on the long run cost of production.

3.1.2. Estimation of the energy subsidies based on 2012 data

3.1.2.1. Consumer and reference price

3.1.2.1.1. Oil products. Gasoline (Premium & Regular), Gas/Diesel, Fuel oil and Kerosene are the oil products that are included in this paper because they are widely used within the country [52]. The consumer prices for these oil products were taken from multiple sources, the GIZ international fuel prices report for the year 2012 [53], the Saudi Press Agency and the Saudi of Councils of Ministers. Regarding the reference prices like it was mentioned earlier it equals the International price plus taxes and transport costs. The international prices were taken from the Organisation of the Petroleum Exporting Countries' monthly oil market

Table 1
Fuel prices in 2012.

Oil Products		Retail Prices (USD $/ton)	Reference Prices (USD $/ton)
Gasoline	Premium	197.064	1060.447
	Regular	136.374	962.900
Gas/	Industry	99.96	989.148
Diesel	Transport	136.374	
Fuel Oil		45.339	826.24
Kerosene		183.498	1009.631

reports of the year 2012 based on the US Gulf prices. The distribution and marketing costs are based on AFPM's assumptions for the gasoline in the USA for the year 2012 [54]. No taxes are levied on export in the KSA, so no taxes are to be added to calculate the reference prices [55].

Based on 2012 data for gasoline, the average international price was $128.81 USD per barrel, meaning $919.7 per ton. For diesel, the average international price $125.56 per barrel that is $896.5 per ton. Regarding the fuel oil, its average international price is $105.2 per barrel, which equals $751.12 per ton. The international price for kerosene is $128.55 per barrel and $917.84 per ton. Table 1 contains the consumer and reference prices for oil products.

3.1.2.1.2. Natural gas. The pricing for natural gas is more complicated compared to oil products, seeing the unavailability of international prices. Although Saudi Arabia sits under important natural gas reserves [56] it does not play a big role on the international level, seeing that all of what it produced back in 2012 was consumed within the kingdom (IEA, 2013), making the estimation of the reference price more complex. Therefore, in order to do that, the long run marginal cost of production costs is applied following thus the line of natural gas production to determine its cost within Saudi Arabia. The consuomer and reference prices for natural gas are available in Table 2.

A percentage of 57% of the natural gas in the KSA is in the form of associated gas [57], meaning it exists as a joint product with the crude oil. Seeing that producing the crude oil is the main objective in this case, the separation of the two components will happen at some point in the line of the oil production, which makes the actual cost of producing the associated gas zero. The only costs that relates to it is the marketing and distribution, which costs USD $2 per million Btu, based on Alyoussef and Stevens research (2011). Regarding the non-associated gas, its production was estimated to range between $3.5 and $5.5 per million Btu [58]. The consumer's price for natural gas (NG) for 2012 was taken from Reuter's official site [90].

3.1.2.1.3. Electricity. Electricity is a very important source of energy in Saudi Arabia, especially on the social level since issues like access and poverty are always brought up with it. That is why the Saudi government in order to support the economic growth of the country lowered the residential tariff compared to other sectors. A study led by the French Institute of International Relations [8,9] showed that the residential sector is the highest consumer of electricity in KSA with 50% produced, followed by the industry, the commercial sector and the governmental agencies with 21%, 15% and 12% respectively between the years 2004 and 2013.

The electricity is not a tradeable fuel like oil, so the estimation of the reference price is based on the long run marginal cost of production plus the costs of transmission and distribution (Alyoussef and Stevens, 2011). The data for the end-user prices and the cost of generating electricity were taken from the Saudi Electricity Company [59] and they are listed in Table 3.

Table 2
Natural gas prices.

	Consumer Price (USD$/mBtu)	Reference Price (USD$/mBtu)
Natural Gas (NG)	0.75	3.935

Table 3
Electricity prices for 2012.

	Consumer Prices		Reference Price	
	RSA/KWH	US$/KWH	RSA/KWH	US$/KWH
Residential	0.075	0.020	0.375	0.100
Commercial	0.22	0.058		
Gov Agencies	0.26	0.069		
Industrial	0.12	0.032		
Agriculture	0.1	0.026		
Other	0.2	0.053		

3.1.3. Price elasticities of demand (PED)

The Price elasticity of demand is a measure of a variable's reaction to another variable change. It describes to which extant a demand for a good or service changes with its price.

The data for the energy price elasticity of demand in Saudi Arabia is based on secondary resources due to data and time limitations. Krichene [60] analysed the price elasticity of demand and supply of crude oil and natural gas over the world's market, he estimated the PED of natural gas as −0.48. Dargay and Gately (2010) studied the impacts of price and income changes on oil demand. They estimated the price elasticity of demand for gasoline, diesel and kerosene as −0.09, −0.12 and −1 respectively in the oil exporting countries. Due to the absence of any data regarding price elasticity in KSA, this paper will use the data from the OECD countries as benchmark. Madlener et al. [61] led a research for the E.ON research centre to quantify the impact of the economic activity and energy price on the energy demand. They estimated the price elasticity of demand as −0.139 for residents and −0.55 for industry. Table 4 summarises the price elasticity of demand for energy in KSA used in this paper.

3.2. The impact of energy subsidies reform

Seeing the high spending of Saudi Arabia on end users' energy subsides, a well-structured reform program should be implemented by the government to guarantee sustainability of its oil and gas resources. Although these subsidies may achieve some of their goals, they can be very costly for the country, in terms of financial burden, overconsumption of energy and great amount of waste and cause an important increase in GHG emissions. However, a total or partial removal of energy subsidies could have a subsequent effect on the kingdom's whole economy, as higher energy prices would have direct and indirect effects on different sectors, seeing that would mean an increase of inputs leading then to higher production costs in the country's different industry sectors. That is why a quantitative representation is very meaningful, as it allows a proper analysis of the impact of energy reform, hence the application of the Input-output model.

3.2.1. Input-output model

The Input-Output model was founded by the Nobel Prize winner Leontief in 1930 [62], and it represents the interdependency of national industries in the country. The model's main purpose is the establishment of the establishment of a tessellated input-output table through a system

Table 4
Price elasticity of demand.

	Price Elasticity of demand
Electricity	
Industry	−0.55
Resident	−0.139
Oil Products	
Gasoline	−0.09
Diesel	−0.12
Kerosene	−1
Fuel Oil	−1.02
Natural Gas	−0.48

of linear equations [63]. The model is carried out in order to estimate the macroeconomic effects induced by the phasing out of energy subsidies. The Input-output model was used seeing its simplicity, transparency and well establishment when compared to other approaches such as the Partial Equilibrium or Econometric Models [64]. Furthermore, when focusing of an analysis of one-shot policy shock such as the elimination of the energy subsidies, the Computable General Equilibrium model (CGE) may developed by Lofgren and Robinson [65] seem more suitable seeing it has more depth and gives a more comprehensive economic relationship between sectors. However, the method requires a lot of complex data, unlike the I–O model [26], hence the choice of using the I–O model.

3.2.2. Steps of the quantitative analysis

A change of price in one sector can lead to price changes in others, either in a direct or indirect way. Assuming a country's economy is based on n sectors which are interdependent seeing that one sector's output could be used as an input in another sector. The main equation of this model is as followed:

$$X = (I - A)^{-1} Y \tag{7}$$

$$\begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} = \begin{pmatrix} 1 - a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & 1 - a_{nn} \end{pmatrix}^{-1} \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \tag{8}$$

where: X: n*1 vector of sector output.
Y: n*1 vector of final demand.
A: n*n matrix of technical coefficients.
X_i: Total output of sector i.
x_{ij}: Sales from sector i to sector j.
y_i: Final demand for the product of sector i.
The technical coefficients reflect the direct and indirect effect of a price change in one sector on the others. Where:

$$a_{ij} = \frac{x_{ij}}{X_j} \tag{9}$$

For reasons of unavailability, all the estimations for this model are based on the Input output table published by the OECD [66] for 2011 for KSA. The data for this I–O table might be considered inaccurate, as the price level and sector classification of an outside organisation (OECD) could differ from the ones published domestically. Furthermore, the I–O table was for the year 2011, as the data for 2012 are not available; these limitations may cause some deviations within the final results, but it will give a clear picture of the effects of subsidy removal. The Saudi economic sectors were categorized into 36 domestic industrial sectors based on their activities, and the $ US was used as the monetary unit.

Each price adjustment scheme within a country has different effects on its economy sectors, and an increase in energy prices will definitely trigger great changes in them. The Sensitivity analysis is used in this paper to describe the impact of energy prices change on different sectors of the Saudi economy [62]. The formula is as followed:

$$S_i = \left| \frac{X'_i}{Y_m} \right| \tag{10}$$

where: X'_i The price change in each sector.
Y_m: The energy price increase.

Table 5
Saudi Arabia energy consumption in 2012 [67]].

Electricity (GWH)		Oil Products (1000 Tonnes)	
Industry	32075	Gasoline	20624
Resident	120464	Diesel	20541
Commercial & Gov services	74054	Fuel Oil	9329
Agriculture	4191	Kerosene	1041
Others	523	Natural gas (TJ)	1419387

4. Findings

4.1. Saudi Arabia energy subsidies for 2012

The statistics for the kingdom's energy consumption for the same year were taken from the IEA [67] official website (Table 5).

Table 6 represents Saudi Arabia's end-use fossil fuel subsidies for the year 2012, its energy consumption and carbon dioxide emission in the case of a total subsidy removal. The results show that the kingdom's consumers' subsidies amount to USD 80.073 billion, equivalent to 10.90% of the country's GDP. IEA [42,43] estimated that Saudi Arabia's end-use energy subsidies amounted for USD 60.9 billion in 2011. The sharp increase estimated within the findings could be a result of the increase in energy consumptions between 2011 and 2012, as it increased from 219.8 to 233.1 million metric tons of oil equivalent [68]. In addition to overall energy consumptions, the prices of crude oil were at high levels in 2012, continuing the trend from 2011, the Brent crude oil experienced a slight increase between 2011 and 2012, increasing from USD 111.26 to USD 111.67 per barrel (EIS, [82]).

4.1.1. Oil products

Most of Saudi Arabia's energy subsidies go to oil products, its subsidies only counts for more than $60 billion and up to 75.65% of the total energy subsidies, making it the biggest beneficiary of government support. The oil subsidies' share in the country's GDP is a percentage of 8.25%. In terms of type of oil products, gasoline was the most subsidised fuel, with an amount of over $34 billion and a 4.74% share in the GDP, followed by diesel, fuel oil then kerosene.

The reason for this heavy subsidy of both gasoline and diesel is the great gap between the reference and retail prices, plus their high consumption compared to other fuels seeing that the country has almost no public transportation and is geographically vast. Another reason for the KSA's high oil subsidies is the fact that it is the world's largest oil exporter and producer [56] and has been for years. Therefore, it is easy for the kingdom to offer its citizens oil for cheap prices. Moreover, in a country where the fossil fuel production is controlled by the government, citizens see that it is within their rights to get low energy prices [12].

Fuel oil is mainly used in the power generation or water desalination sectors, with a 6% used to generate electricity for the most part of the Western region [69] in 2012. That is why its estimated end-user subsidies are lower compared to gasoline and diesel. Usually in estimations of energy subsidies using the price-gap approach, the subsidies of kerosene are not included, seeing it is slightly consumed and it exists a

Table 6
Saudi Arabia Subsidies and the effect of its removal in 2012.

Energy	Subsidy ($ Billion)	Share of total Subsidies (%)	Share of GDP (%)	Potential Energy Saving	Potential CO_2 Saving (BKg)
Oil Products (1000 T) Gasoline	34.85	43.526	4.748	3.089 **(Mtoe)**	0.872
Diesel	17.58	21.965	2.396	4.617 **(Mtoe)**	1.490
Fuel Oil	7.25	9.060	0.988	88.459 **(Mtoe)**	3.314
Kerosene	0.86	1.074	0.117	0.8518 **(Mtoe)**	0.263
Natural Gas (TJ)	4.28	5.351	0.583	738.189 **(MTJ)**	3.9212
Electricity (GWH)	15.23	19.023	2.0753	3.145E+10 **(GWH)**	
Total	80.07	100	10.909		

wide variety of kerosene with significant variation in the price [70]. This was obvious, where its share in the total oil subsidies barely exceeded 1%.

Most of the oil products have no substitutes for the time being (apart from fuel oil), that is why their PEDs are under one (Table 4), and since their value is negative the possible energy savings for the oil products reached over 17.4 million tonnes about 33.77% of the oil products' current consumption. This decline in consumption could lead to a reduction of 59.41 billion kilogram of CO_2.

In terms of oil products, fuel oil has the highest potential savings with 8.8 million tonnes and a CO_2 reduction of 3.31 billion kilogram. This is because the fuel oil can be easily replaced by natural gas; this is seen in Saudi Aramco's plans to expand natural gas production. In addition, natural gas is way cleaner that fuel oil that contains 11.7 kg CO_2 per gallon [71]. Kerosene comes second in energy savings and third in CO_2 reduction with an 8.5 million tonnes and 0.26 billion kg of CO_2.

4.1.2. Natural gas

The Saudi Arabia's natural gas subsidies are considered the lowest of the country energy subsides; it counts for US$4.28 billion and represent about 5.35% of the whole energy subsidies. The kingdom would consume 6.07 10^8 MMBtu in the case of subsidy removal, instead of the 13.45 10^8 MMBtu that have been consumed in 2012, meaning that an amount of 7.38 10^8 MMBtu would be saved, which accounts for up to 54.87% of the 2012 consumption. Regarding carbon dioxide emissions, a value of 39.9 million tonnes of CO_2 would be saved with the removal of subsidies; the reason behind this number is the potential saving in quantity consumed.

Even though Saudi Arabia is facing a shortage in natural gas [72] its domestic prices is one of the lowest in the world [8,9], leading to high demands from large users, especially petrochemical companies. The low prices may have a positive impact on the development of the petrochemical industries in KSA, but this does not encourage investments to improve its infrastructure (process & transport) and energy use.

4.1.3. Electricity

Electricity's net subsidies represent a great amount of the country's amounting to 19%, with US$ 15.23 Billion and approximately 3% of the country's GDP, where most of it goes to the residential sector. The subsidy amount is a result of the combination of the growing population due to the kingdom's thriving economy and its hot weather conditions. The electricity demand experiences a sharp rise up to 7%–8% during the last decade [8,9], and its consumption grows heavily specially in the summer period, 40% more than in the winter [72] because of the need for air-conditioning.

In the case of the subsidy removal, electricity consumption would decrease to amount to 86% of its current consumption, yielding 14% of electricity saving. This amount would cause a great carbon dioxide reduction, seeing that most of the electrical power is generated by burning petroleum products. Especially, since the Saudi Electricity Company relies heavily on the burning of the subsidised oil products, with the absence of either nuclear or large-scale renewable energy projects.

With the removal of subsidies, and in terms of sectors, the demand in the residential sector would drop slightly but remains strong consuming up to 49% of the produced electricity, followed by the commercial and governmental services sector that would increase lightly to represent approximately 36% instead of the 32%. While the demand in the industrial and agricultural sectors remained constant with insignificant changes, at 14% and 2% respectively.

4.1.4. CO2 emissions

The overall effect of a total subsidy removal on carbon dioxide emissions is a reduction of 1.89%, with the majority from Fuel Oil and Natural Gas. This estimation represents the potential of CO2 in the country's major sectors that are expected to be affected by subsidy reform, such as transport, construction, chemical industries and power plants. This potential decrease goes in line with the world's vision and sustainable development goals by having climate actions within the country's futuristic plans.

However, during the 2016 Paris Agreement, it was obvious that Saudi Arabia does not a clear emission path towards 2030, as it has not revealed a baseline relating to its national determined contribution target. The exchange of economic and environmental outcomes of fossil fuel subsidies is to be determined by the energy mix within the Saudi economy, as it relies heavily on oil and gas. Specially, transportation, chemical industries and power plants that are mainly dependent on oil to generate electricity and desalinate the sea water. The country has yet to invest a lot into more clean energy sources as wind and solar energy. Furthermore, Saudi Arabia is yet to set up an environmental protection policy to follow the footsteps of the rest of the world.

4.1.5. The effect of energy price increase due to energy subsidy reform

In order to study and quantify the impact of energy subsidy reform of the Saudi economy, two scenarios are set up and simulated. The first scenario models Saudi Arabia where all the energy subsidies are eliminated with no redistribution of savings, which is shown in Table 7. The second scenario treats a case where the subsidies is not totally eliminated, but reduced by 50%, which would be allocated to education, health and community services' sectors. Results of the simulation of scenario 2 is shown in Table 8.

The simulation of the first scenario, where all energy subsidies were removed, shows that all of Saudi Arabia's economy sectors will be affected by the increase of energy prices, in different proportions, since the subsidised energy products are integrated within all of the kingdom's economic sectors. The results show that apart from the energy sectors which are affected directly, the mining and quarrying sector alongside with machinery and transport sectors and the metal industry are the most impacted by energy prices change. Whereas, most of the tertiary sectors, such as hotel and restaurants, real-estates and banking are the least affected by the increase of energy prices. The industries that are impacted the most are the energy intensive ones, such as the mining and quarrying industry with a sensitivity of 1.3687%, followed by industries that produce refined petroleum products, electricity and natural gas, with a sensitivity of 0.7906 and 0.2587 respectively. However, other industries like the petrochemical, metallurgical and transport industries that are supposed to be more sensitive to energy prices changes, seeing that they need a high amount of energy to operate, the results of the simulation show that the sensitivity of three industries put together do not surpass 0.030.

The results of the second scenario indicate that total removal of energy subsidies and reallocation of 50% of its savings into education, health and social work can have a positive impact on most of Saudi Arabia economy, apart from industries that are energy intensive. The mining and quarrying, production of refined petroleum products, natural gas and electricity industries still suffered from energy prices increases, with a minor decrease in sensitivity compared to the first scenario, reaching 1.3128, 0.7840 and 0.2518% respectively. The reallocation of a part of the savings to social programs affected positively

Table 7
Sensitivity of the economy sector in case of scenario 1.

Scenario 1	
Economy Sectors	Sensitivity
Mining and Quarrying	1.368
Coke and Refined petroleum products	0.790
Electricity, Natural Gas and water supply	0.2587
Chemicals and Chemical products	0.0074
Metallic products, Basic Metals	0.0187
Transport and Storage	0.0123
Education	0.0063
Health and social Community work	0.0066

Table 8
Sensitivity of economy sector in case of scenario 2.

Scenario 2	
Economy sectors	Sensitivity
Mining and Quarrying	1.312
Coke and Refined petroleum products	0.784
Electricity, Natural Gas and water supply	0.2518
Chemicals and Chemical products	0.0119
Metallic products, Basic Metals	0.0116
Transport and Storage	0.0029
Education	0.1646
Health and social Community work	0.4058

Saudi's economy and especially the health and social work sector, with a sensitivity of 0.2167, followed by community work and education. This focus on public expenditure could really benefit the country on a social level, especially since the government spends way more on energy related programs than it does on social ones [73] and the difficulties that it faces financing the health care services [74].

The reform of energy prices is still a political and economic challenge for the Saudi government. The political disputes that happened in the Arabic world in 2011 can be a reason for the government's unwillingness to total elimination of subsidies, but seeing the negative impacts of energy subsidies on the country's economy, society and environment makes the government think seriously about a reform program, but a non-well studied subsidy reform may lead to serious consequences, especially within the household's welfare and energy intensive industries. So in order avoid any political riot, the government should opt for a gradual reform option instead of a complete removal of subsidies; the prices' increase should be separated into several steps over several months or even years depending on the reaction of the population for each price change. With the gradual increase of prices, the economy would have enough time to adapt to the energy prices rise and implement mitigation measures.

In order to reduce the subsidies reform's costs the government could couple the reform programs with one or a combination of mitigation measures, this can preserve the welfare of the society and economy of the country. With the implementation of mitigation measures, the government can secure the protection of the poor class against any decrease of their income; it can also insure the stability of the internal demand base for local business and companies. Besides, the mitigation schemes could ease up the prices reform in the eyes of the public, especially within the low-income households. Based on Fattouh and El-Katiri (2015) research and the Iranian and Yemen's experience several conditions could play an important part of the success of the energy price reform, such as the amount of the price increases, the government's fiscal soundness, the current social and economic situation of the country and finally how effective are the existing social nets.

- **Targeted Energy Subsidies:** This mitigation scheme does not tend to eliminate all energy subsidies; it eliminates, reduces or keeps some subsidies depending on the sector and the social group that is benefiting from it. The Iranian government undertook this plan in their major 2010 energy price reform [75]. By eliminating and keeping some subsides, the government would limit the beneficiaries to specific groups of society, they can cover some industries that depend heavily on low energy prices to secure their financial profit and keep their international competition alive, such as the petrochemical industry in Saudi Arabia. The government could also keep subsidies on fuels that are consumed heavily amongst the poor class of the country, or fuels that are relatively cleaner compared to the others or electricity. Jordan for instance, in its 2012 subsidies reform the government kept the subsidies for the LPG seeing its low carbon emission [91]. To avoid subsidies primal problem, high-income households taking advantage of the subsidised fuels, the government could target directly the groups that could benefit from the remaining subsidises. However, Van de Walle [76] argues that implementing the targeted subsidies could be difficult seeing it requires a lot of information, which may cost a lot and cut an important part of the price reform savings.
- **Targeted Cash Transfers:** The perfect price reform would be the total elimination of all energy subsidies and direct all savings towards financing social programs to help the unfortunate groups of the society. This mitigation program is basically based on two targeting plans, administrative and self-targeting mechanisms [92]. Regarding the administrative targeting, the scheme's administrators decides the beneficiaries of the program based on several standards such as income or social class. For the self-targeting mechanism the members of the population would decide whether to or not participate in the program. On one hand, the targeted cash transfers do not restrict its beneficiaries to energy consumption; it gives them the choice to use the financial aid on what they desire. In addition to that, the scheme do not promote wasteful energy consumption that, either targeted subsidies may hint to. On the other hand, implementing this program could be hard, seeing the difficulty of classifying the beneficiaries and identifying the income levels, to separate the poor from the rich.
- **Use of existing social nets:** This program is both fast and cost effective, since it invests the savings of prices reform into the existing social safety nets, by expanding and strengthening them. For instance, the government could increase the worker's wages in the public sector and think of a compensatory plan for employees in the private sector. Syria in 2008, when its government decided to increase energy price, it increased the public sector's wages as well [77]. The government can also invest more into the unemployment insurance scheme, seeing that Saudi Arabia did not introduce it until 2014 [78].
- **Focus in Public Expenditure:** The government could invest some of its reform savings to improve the pro-poor sectors, like the health and education systems. The challenges accompanying such investments are numerous, but the country would definitely gain profit from it in the long term. The government could also invest industries generating profit or supporting energy efficiency.

No matter the energy price reform adopted by the government, a long-term plan should be taken into consideration to prevent any possibility of getting back into energy subsidies. The automatic adjustment mechanism is proven to be an effective tool in reforming systems [79], it is used widely in reforming pension schemes around the world. With the introduction of such log-term plan, the domestic prices would be updated regularly, keeping the energy prices within a rational range from the international prices; this would protect the domestic markets against fuel prices constant changes.

5. Conclusion

This research used the price-gag approach to estimate the size of Saudi Arabia's subsidies in 2012, and the effects of removing these subsidies regarding Carbon dioxide emissions, energy conservation and impact on the country's economy sectors. Even though the estimations were made just for the end-user consumers, the size of Saudi Arabia's energy subsidies are still considered to be high, about $80 billion representing up to 11% of the country's GDP in 2012. In the case of energy subsidies removal, the country could save up to 17.04 million ton of Oil products, 7.38 10^8 MMBtu of Natural gas and 3.14 10^{10} GWH of electricity, the country could also save up to 98.68 billion kg of CO2. Thus, the elimination of energy subsidies will lead to an increase in energy prices accompanied with a reduction of Carbon dioxide emissions and an improvement on energy consumption. Mainly the industries with energy intensive would be the most affected by an increase in energy prices, especially the mining and quarrying industry, production of refined petroleum products, electricity and natural gas industries.

In terms of energy types, oil products are the most subsidised in Saudi Arabia, due to their heavy consumption, the kingdom spends on them 75.62% of the total subsidies, with most of it going to gasoline that its subsidies represent 43.5% of the total followed by diesel with 21.9%. This could be because of the great difference between the international prices, that saw a sharp rise during that period, and the domestic prices of oil back in 2012. Electricity's subsidies are second behind oil products, representing 15.23% of total subsidies, while Natural gas only represent 4.28%, seeing that it still not fully explored.

The input-output model was used to quantify the impact of energy subsidy removal on the different economy sector of Saudi Arabia. Two scenarios were simulated; the first one is the total removal of energy subsidies with no redistribution of the savings; the second scenario models the case of a total energy subsidy removal with a reallocation of 50% of the savings into social and health sectors. In both scenarios, energy intensive industries are the most affected by energy prices increase; but it has to be noted that the results of the second simulation show that a redistribution of savings would have a positive impact on most of the economic sectors.

With Saudi Arabia's fast growing economy (based on oil) and population, the existence of some energy subsidies may seem justifiable or even a necessity. Governments rational behind providing energy subsidies are generally for socioeconomic or political reasons, such as improving the social welfare of the poor class of the country, supporting domestic industries and strengthening their international competitiveness and the most important reason is winning the citizens' support for political considerations. However, because of either over-subsidisation or a poor subsidy programs, these subsidies may be doomed to fail from the start, and may even end up contradicting their original objectives of the kingdom. That is why it is very important for the Saudi government to reform its current subsidy programs to ensure a sustainable future for its population. In order to do that, the government should take into consideration the effects on the economy, environment and society, especially with the political problems that the Arab world is facing, energy efficiency and environmental difficulties that Saudi Arabia is having. For these reasons, the Saudi government should be careful when adopting any reform policy since it can be socially, economically and politically challenging.

The UNEP and IEA [80] set principles for energy subsidies: What product would be subsidised, how it should be payed and how big the size of the subsidies should be. Therefore, four frameworks have to be taken into consideration in the case of an introduction or a reform of energy subsidies: the object and scope of the subsidy, the manner to pay it and its amount. When reforming energy subsidies, the Saudi government should take into consideration that: the subsidies (i) have to be more targeted and effective (ii) have to guarantee that all citizens, precisely the poor, get access to the modern energy to cover their needs.

This research estimated the energy subsidies of Saudi Arabia and the impact of their removal from an economic perspective, doing a research from an environmental, public health or energy security perspective could be a possible extension for future studies, in addition to including producers' subsidies. Furthermore, the use of a Computable General Equilibrium model (CGE) instead of the input-output one could be very useful to estimate the changes on Saudi Arabia's economy on a macro level in the case of subsidy removal, which would give results that are more accurate.

Authors contribution

Redouane Sarrakh: Conceived and designed the analysis, Collected the data, contributed data or analysis tools, Performed the analysis, Wrote the paper. Dr Suresh Renukappa: Provided re-check of the analysis performed and proof-read the paper. Dr Subashini Suresh: Provided editing of the analysis and proof-read the paper. Dr Mushatat Sabah: Provided editing of the analysis and proof-read the paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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